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ENHANCEMENT OF POWER QUALITY USING FUZZY CONTROLLED D-STATCOM IN DISTRIBUTION SYSTEM

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ABSTRACT

The problems associated with distribution system in terms of delivery of clean power and their solutions are investigated through this paper. Power quality has become a major issue in the present power system network. The network is mostly inductive in nature so it draws more reactive power. This causes harmonics and voltage flickering. To maintain the proper operation of interconnected power system, we use one of the facts devices such as fuzzy controlled D-Statcom which provides suitable compensation and thereby maintains proper power factor and also reduces harmonic contents. The simulation is taken out by MATLAB/SIMULINK Hence optimized Fuzzy controlled D-STATCOM can be used for improvement of power quality. Fuzzy controlled D-Statcom improves power quality and stability for Distribution of power system

KEYWORDS: Distribution Static Compensator (D-Statcom), Hysteresis Controller, Fuzzy Logic, PI Controller, Fuzzy Logic Controller & Total Harmonic Distortion (THD)

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I. INTRODUCTION

Power quality is the key to successful delivery of good quality power. The typical loads such as computer loads, Lighting loads, refrigerators, other domestic and other commercial loads[1].A distribution system suffers from current and voltage related problems which include poor power factor, distorted source current, A statcom connected at the point of common coupling has been utilized to reduce above problems[2]

There are various controllers used for in distribution system those are static var capacitor(SVC), The thyristor controlled series capacitor(TCSC), Static synchronous series compensator(SSSC),The unified power flow controller(UPFC),And interline power flow controller(IPFC).Among them Dstatcom is very well known and can provide cost effective solution for reactive power compensation.[3]. Conventionally PI have been use as regulates of Dstatcom conventional PI controller has limitation over its operating range. It is highly in efficient during non linear operation.[5].

The main advantage in the use of fuzzy controlled Technique is to allow designer own experimental effort for adjustment of controlling parameters. In this paper we use Sugeno fuzzy controlled D-statcom which is used to reduce harmonics, and power factor correction and maintain the voltage at the load terminal. Fuzzy controlled D-Statcom connected for the point involving common coupling (PCC), it injects reactive along reactive along with

harmonic different parts of load currents to generate source currents nicely balanced.

II. ANALYSIS OF D-STATCOM

The D-STATCOM is a three-phase and shunt connected power electronics based device. It is connected near the load at the distribution systems. The major components of a D STATCOM are shown in Figure 1. It consists of a dc capacitor, three-phase inverter (IGBT, thyristor) module, ac filter, coupling transformer and a control strategy. The basic electronic block of the D-STATCOM is the voltage-sourced inverter that converts an input dc voltage into a three-phase output voltage at fundamental frequency

Figure 2. Shows the single phase equivalent representation of Figure 1.variable is switching function, and can be either or depending upon switching state. filter inductance and resistance are and. respectively. Shunt capacitor eliminates high switching frequency components. first discrete modeling of the system is presented to obtain a discrete voltage control law. And it is shown that the pcc voltage can be regulated to the desired value with properly chosen parameters of the vsi

Then a procedure to design VSI parameters is presented. A proportional –integral controller is used to regulate the dc capacitor voltage at a reference value.

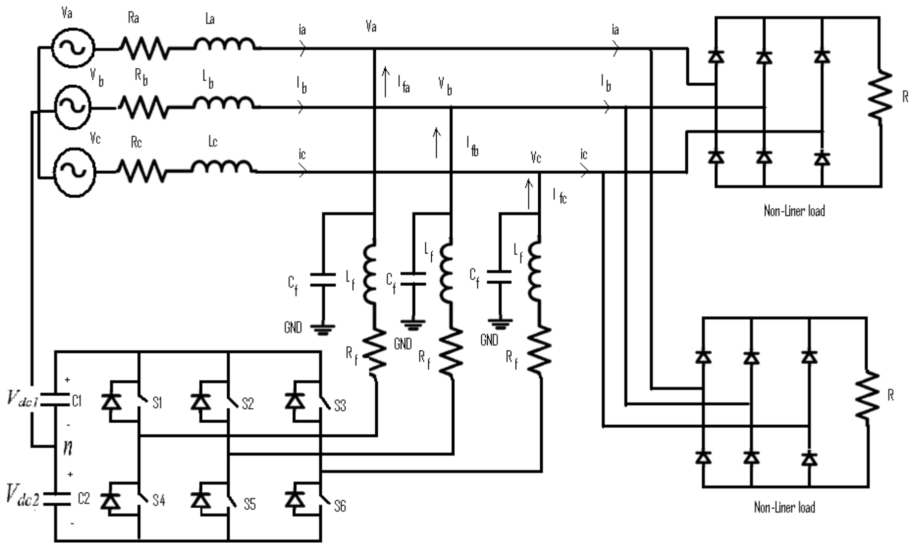

Figure 1: System Configuration of Three Phase DSTATCOM

III. CONTROL ALGORITHM

Instantaneous D-Q Theory

Instantaneous **d-q** Theory was initially proposed by Akagi. This theory is based on the transformation of three phase quantities to two phase quantities in d-q frame and the instantaneous active and reactive power is calculated in this frame. Sensed inputs V_a, V_b and V_c and i_a, i_b and i_c fed to the d-q controller and these quantities are processed to generate reference commands which are fed to a hysteresis based PWM current controller to generate switching pulses for D-STATCOM.

The system terminal voltage are given

$$\left.\begin{aligned} V_{a=} V_m \sin(wt) \\ V_{b=} V_m \sin(wt-120^0) \\ V_{c=} V_m \sin(wt-240^0) \end{aligned}\right\} \quad \text{(I)}$$

And the respective load currents are given as

$$\left.\begin{aligned} I_{a=} I_m \sin(n(wt)-\theta_{an})) \\ I_{b=} I_m \sin(n(wt-120^0)-\theta_{bn})) \\ I_{c=} I_m \sin(n(wt+120^0)-\theta_{cn})) \end{aligned}\right\} \quad \text{(II)}$$

In a, b and coordinates a, b and c axes are fixed on the same plane apart from each other by 120^0.These vectors can be transformed into d-q coordinates using Clarke's transformation as follows.

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \sqrt{\frac{2}{3} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix}} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

Where d and q axes are the orthogonal coordinate's .conventional instantaneous power for three phase circuit can be

$$P=V_d I_d+V_q I_q \quad \text{(III)}$$

where I_d and I_q are d and q axis coordinate currents

Where p is equal to conventional equation

$$P=V_a I_{a\,+}\, V_b I_{b\,+}\, V_c I_c \quad \text{(IV)}$$

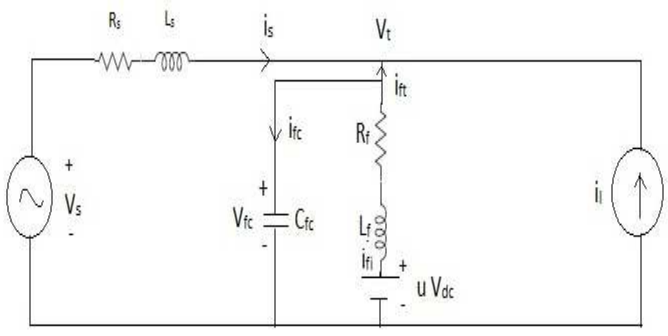

Figure 2: Single Phase Equivalent Circuit of DSTATCOM

Applying the Kirchhoff's law for above circuit

$$V_S = I_S(R_S) + L_S \frac{di_s}{dt} + V_{fc}$$

$$I_S^* = \left(\frac{-1}{L_S}\right)V_{fc} + \frac{V_S}{L_S} + \left(\frac{-R_S}{L_S}\right)I_S$$

$$C_{fc}\frac{dV_{fc}}{dt} + I_{ft} = I_{fi}$$

$$V_{fc}^* = \frac{I_{fi}}{C_{fc}} - \frac{I_{ft}}{C_{fc}} \longrightarrow \text{(a)}$$

$$L_f \frac{dI_{fi}}{dt} + I_{fi}R_f + V_{fc} = uV_{dc} \longrightarrow \text{(b)}$$

$$I_{fi}^* = \left(\frac{-1}{L_f}\right)V_{fc} + \left(\frac{-R_f}{L_f}\right)I_{fi} + u\frac{V_{dc}}{L_f} \longrightarrow \text{(c)}$$

Using above three equations (a), (b) and (c) to represent state space model

The State space equation for the circuit shown in figure 2 are given by

$$\dot{x} = Ax + Bz \qquad (1)$$

$$A = \begin{bmatrix} 0 & \frac{1}{C_{fc}} & 0 \\ \frac{-1}{L_f} & \frac{-R_f}{L_f} & 0 \\ \frac{-1}{L_a} & 0 & \frac{-R_a}{L_a} \end{bmatrix} \quad B = \begin{bmatrix} 0 & \frac{-1}{C_{fc}} & 0 \\ \frac{V_{dc}}{L_f} & 0 & 0 \\ 0 & 0 & \frac{1}{L_a} \end{bmatrix}$$

$$x = [v_{fc} \quad i_{fi} \quad i_s]^t$$

$$z = [u \quad i_{ft} \quad v_s]^t$$

$$x(t) = e^{A(t-t_0)}x(t_0) + \int_{t_0}^{t} e^{A(t-\tau)}Bz(\tau)d\tau \qquad (2)$$

The general time Domain solution state vector x (t) given by equation (2)

IV. DESIGN OF FUZZY LOGIC CONTROLLER

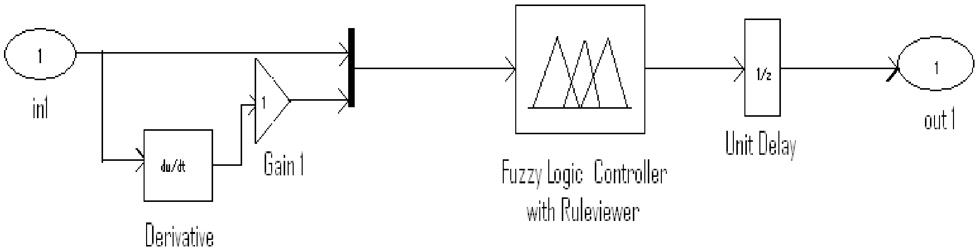

Figure 3: Block Diagram of Control System Block Diagram

Following linguistic values:

NEB: Negative big.

NES: Negative small.

POS: Positive small.

POB: Positive big.

e \ de	NEB	NES	POS	POB
NEB	NEB	NEB	NEM	ZE
NES	NEB	NEM	ZE	POM
POS	NEM	ZE	POM	POB
POB	ZE	POM	POB	POB

Figure 4: Fuzzy Logic Rulebase

The above linguistic quantification has been used in this paper to specify a set of rules or a rule-base. The rules are formulated from practical experience. For the FLC with two inputs and four linguistic values for each input, there are $4^2 = 16$ possible rules with all combination for the inputs. The tabular representation of the FLC rule base (with 16 rules) of the fuzzy control based DC voltage regulator is shown in figure 5

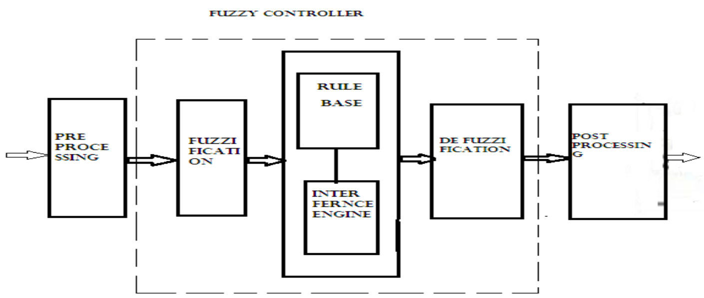

Figure 5: Fuzzy Logic Controller

The conversion of a fuzzy set to single crisp value is called defuzzification and the reverse process of fuzzification. The member ship functions to be employed for the inputs are of the triangular type where the membership functions for the outputs are singletons. The membership functions for the inputs and the output of the fuzzy controller for the DC voltage regulator as shown figs.

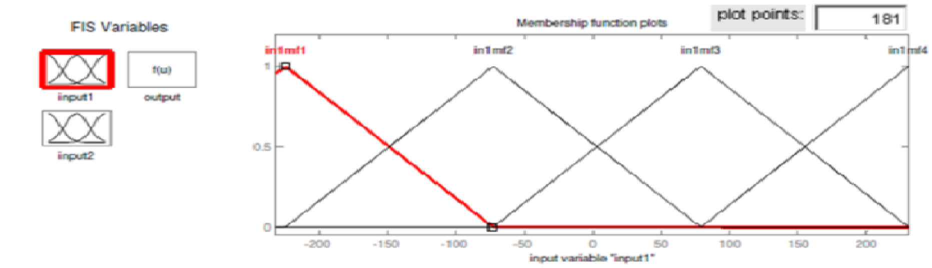

Figure 6: Member Ship Function Ship for Input 1

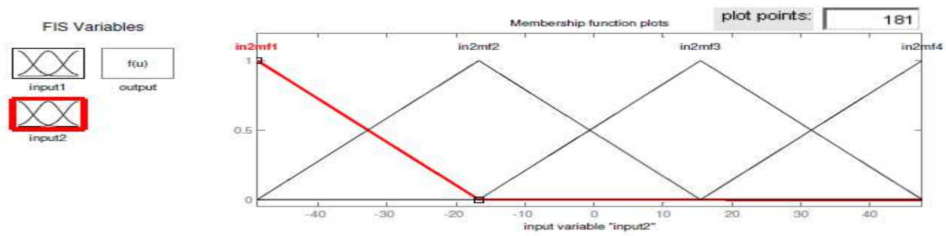

Figure 7: Member Ship Function ship for Input 2

Total Harmonic Distortion

The total harmonic distortion (THD) is used to define the effect of harmonics on the power system voltage. It is used in low-voltage, medium-voltage, and high voltage system. It is expressed as a percentage of fundamental and is defined

According to IEEE-519 the permissible limit for distortion in the signal is 5%.

$$THD(curent) = \frac{\sqrt{\sum_{h=2}^{50} I_h^2}}{I_1} \tag{3}$$

V. HARMONICS ANALYSIS

The load voltage harmonic analysis, using Fast Fourier transform (FFT) of power GUI window by simulink, as shown in Figure 8. It can be seen, without compensation implementation in system total harmonic distortion (THD) of load voltage is 9.38%. Due to harmonics presence in the load side, because of non linear load, it will inject harmonics and disturbs line performance..

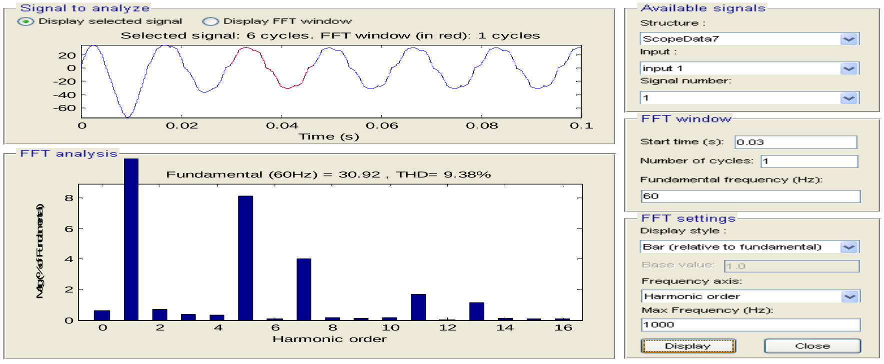

Figure 8: FFT Analysis of System without D-Stat com

The load voltage harmonic analysis, using Fast Fourier transform (FFT) of power GUI window by simulink, as shown in Figure 9. It can be seen, with compensation of D-Statcom implementation in system total harmonic distortion (THD) reduced because shunt connected D-Statcom reduces harmonic content from 9.38% to 5.90%.

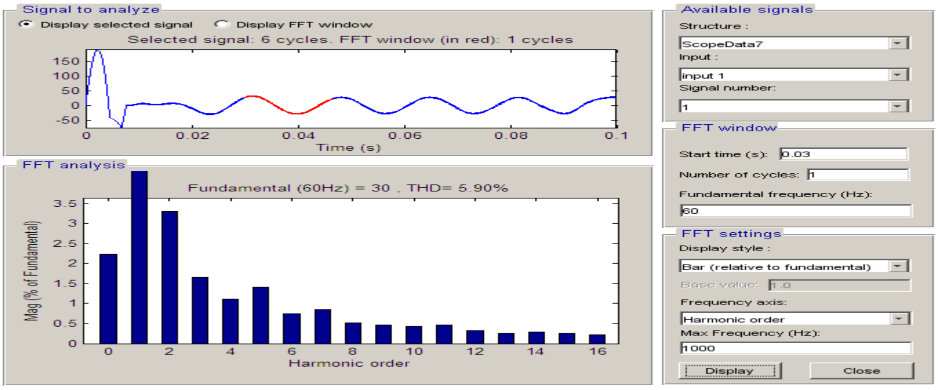

Figure 9: FFT Analysis of System with D-Statcom

The load voltage harmonic analysis, using Fast Fourier transform (FFT) of power GUI window by simulink, as shown in Figure 10. It can be seen, with compensation of D- Statcom with fuzzy control logic implementation in system total harmonic distortion (THD) of load voltage is 4.55%.

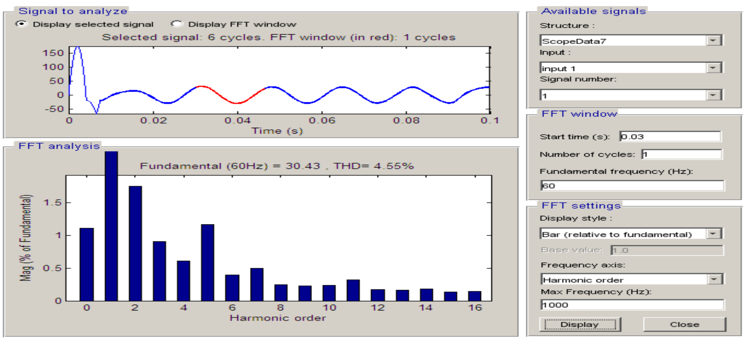

Figure 10: FFT Analysis of System with Fuzzy Controller

VI. SIMULATION RESULTS

Figure 11: Shows Input Supply Voltage 98V RMS Value of the Three Phase System. It is Symmetrical With Respect To Time

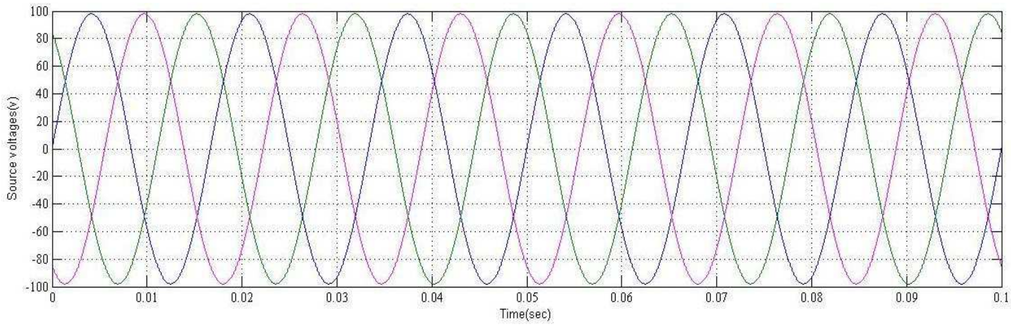

Figure 11: Input Source Three Phase Voltages

Figure 12, 13 and 14 shows the line currents of the distribution system. The line currents are not symmetrical with respect to time due the harmonics present in the system. These harmonics can be reduced by using by Fuzzy Controlled D-Statcom to regulate the output voltage

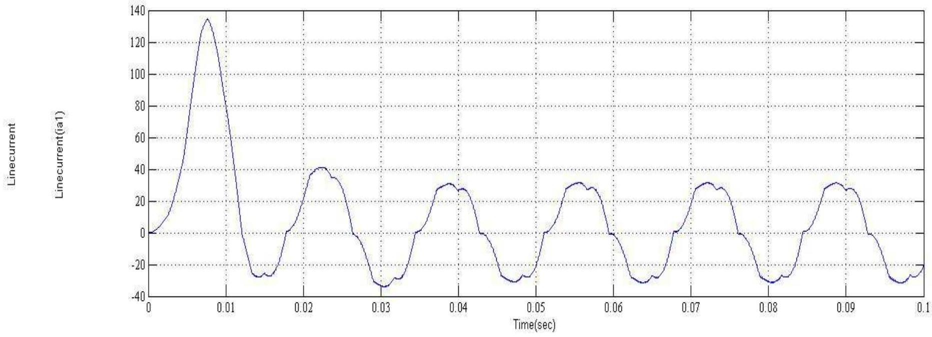

Figure 12: Output Waveform for Line Current 1

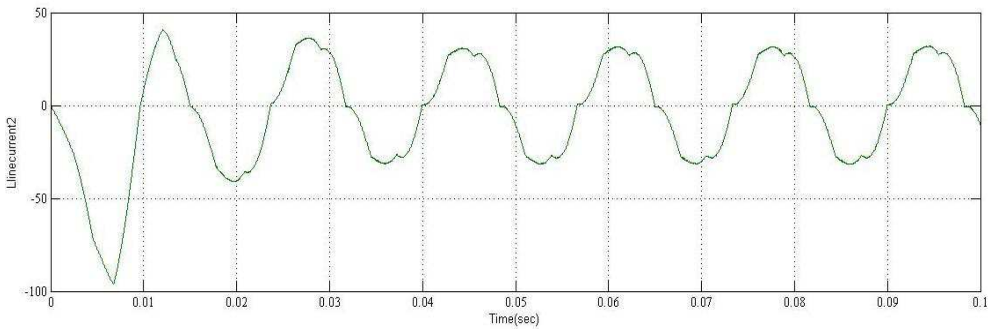

Figure 13: Output Waveform for Line Current 2

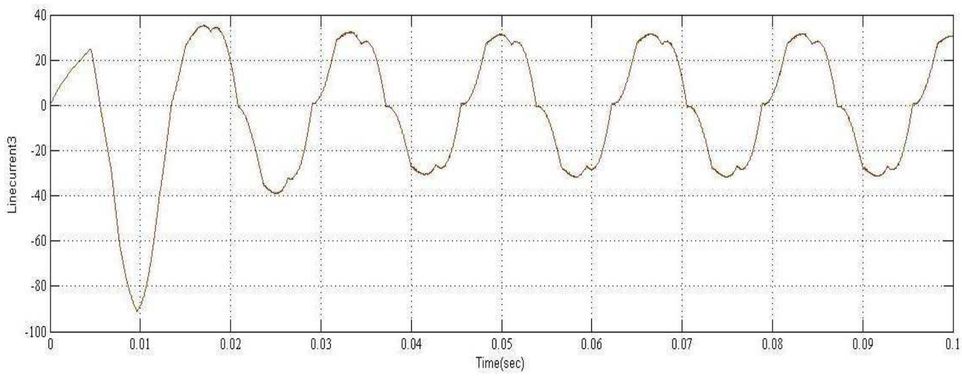

Figure 14: Output Waveform for Line Current 3

Figure 15 and 16 shows load voltage and load current respectively.

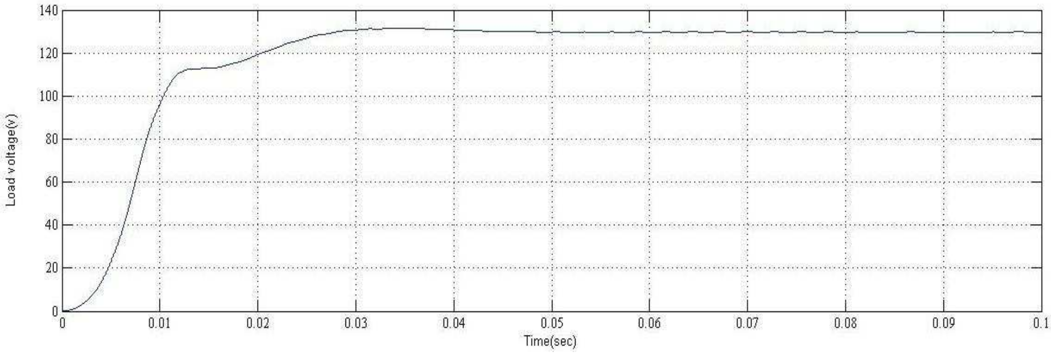

Figure 15: Output Wave Form for Load Voltage

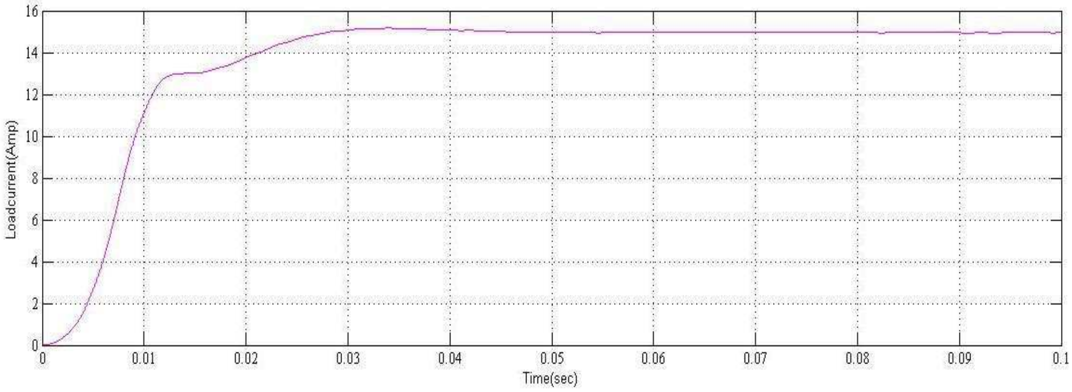

Figure 16: Output Wave Form for Load Current

Comparison between D-Statcom and with fuzzy controlled D-Statcom

Table 1

Comparisons	Without D-Statcom	D-Statcom. (Pi Controller)	D-Statcom (Fuzzy Controller)
THD of source current	9.38%	5.90%	4.55%

System Parameters

Supply Voltage: 98Vrms(L-N),50Hz, three phase balanced

Source Impedance: Rs=0.1Ω ,Ls=0.004H

Nonlinear Load: Three phase full bridge diode rectifier with load(RL=8.6Ω)

DC storage Capacitor Cdc=0.0047F

DC Link voltage Vdc=100V

CONCLUSIONS

This paper is presented the design of fuzzy controller for a DSTATCOM to develop Quality and lively performance of a distribution power system. Comparison study of the Controlled and the optimal fuzzy logic controlled DSTATCOM for improving power quality and lively Performance of a distribution power system which has been by simulated using Sim Power system in MATLAB/simulink environment. The simulation results obtained in MATLAB/Sim

Power systems show that the fuzzy logic controlled DSTATCOM provides enhanced system lively response and hence improve power quality and stability for the distribution power system.

FUTURE SCOPE

Reactive power compensation and harmonics mitigation with fuzzy controller based D-Statcom is more efficient use in further for distribution power systems. It can be further extended Neuron-fuzzy loop controller based on D-Statcom in power distribution system.

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